WIND PROFILES OBTAINED WITH A MOLECULAR DIRECT DETECTION DOPPLER LIDAR DURING IHOP_2002

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ABSTRACT
The Goddard Lidar Observatory for Winds (GLOW) is a mobile direct detection Doppler lidar system which uses the double edge technique to measure the Doppler shift of the molecular backscattered laser signal at a wavelength of 355 nm. In the spring of 2002 GLOW was deployed to the western Oklahoma profiling site (36° 33.500′ N, 100° 36.371′ W) to participate in the International H_2O Project (IHOP). During the IHOP campaign over 240 hours of wind profiles were obtained with the GLOW lidar in support of a variety of scientific investigations.

1. Introduction

The Goddard Lidar Observatory for Winds (GLOW) is a mobile direct detection Doppler lidar system designed for profiling winds in the troposphere and lower stratosphere. In May and June of 2002 GLOW was deployed to the Southern Great Plains of the US to participate in the International H_2O Project (IHOP). GLOW was located at the Homestead profiling site in the Oklahoma panhandle about 15 km east of the SPOL radar (see Figure 1). Several other lidars (Scanning Raman Lidar and HARLIE), radars and passive instruments (Aeribago) were permanently operated from the Homestead site providing a unique cluster of observations. Numerous fixed and mobile ground and airborne instruments, including at least seven lidars, from a variety of international organizations operated during the IHOP observation period (May 14,2002 to June 25,2002). During that period over 240 hours of wind profile measurements were obtained with GLOW. In this paper we will describe the GLOW instrument as it was configured for the IHOP campaign and present examples of wind profiles obtained.

2. Lidar System Description

The GLOW mobile lidar system is designed for studying atmospheric dynamics and transport and also as a testbed to evaluate instrument performance and to validate models used to develop future systems. The Doppler lidar receiver in the GLOW lidar system is based on the double edge technique[1,2]. The double edge method utilizes two high spectral resolution optical filters located symmetrically about the outgoing laser frequency to measure the Doppler shift. The double edge method can be implemented to measure the Doppler shift from either aerosol [3,4] or molecular [1, 2] backscattered signals. The aerosol system operates at 1064 nm where the effects of the molecular scattering are minimal. Conversely, the molecular system operates in the ultraviolet at 355 nm in order to take advantage of the λ^{-4} dependence of the molecular scattering. A number of direct detection Doppler wind lidar measurements have been reported in recent years [5, 6, 7, 8].

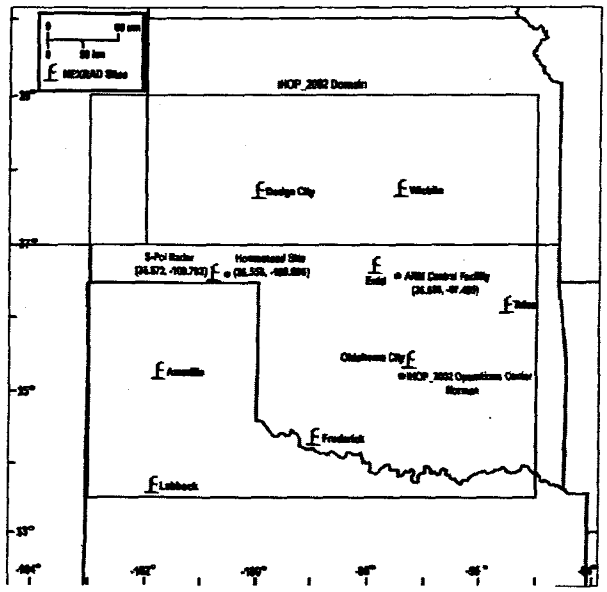

Figure 1 – IHOP_2002 Experiment Domain in the US Southern Great Plains.

A summary of the GLOW lidar system performance characteristics are briefly given in Table 1. The laser is mounted on an optical bench along with the 45 cm aperture telescope which collects the backscattered signal. A 45 cm aperture scanner is mounted on the roof above the telescope and is capable of full hemispherical pointing. The laser is an injection seeded, flashlamp pumped Nd:YAG laser which has a 10 pps pulse repetition frequency. The laser output is frequency tripled to 355 nm for the molecular Doppler wind measurements. The maximum transmitted laser

	Typical / ***IHOP***
Wavelength	355 nm
Telescope/Scanner Aperture	0.45 m / ***0.25 m***
Laser Linewidth (FWHH)	80 MHz
Laser Energy/Pulse	70 mJ / ***5 to 40 mJ***
Etalon FSR	12 GHz
Etalon FWHH	1.7 GHz
Edge Channel Separation	5.1 GHz
Locking Channel Separation	1.7 GHz
Etalon Peak Transmission	>60 %
PMT Quantum Efficiency	15%

Table 1 - GLOW lidar system parameters. Values optimized for IHOP are shown in *italics*.

pulse energy of this laser is typically in the range of 70-80 mJ at 355 nm. The backscattered laser light is collected by the Dall-Kirkham telescope and coupled to a fiber optic cable that delivers the signal to the molecular double edge receiver. In the Doppler receiver, the collimated beam is split into a total of five channels. Three of these beams are directed along parallel paths through a high spectral resolution tunable Fabry-Perot etalon which is used as the edge filter. Two of these etalon channels (the 'edge' channels) have PMTs operating in photon counting mode. These channels provide the information used in the Doppler shift measurement. The third etalon channel is used to sample the outgoing laser frequency as a reference. The other two channels serve as energy monitor channels used to provide intensity normalization of the respective etalon channels during calibration. The photon counting signals are binned in a multi-channel scalar, integrated for a selectable number of shots and stored. For the IHOP experiment the minimum range bins are 45 m (300 nsec) and the minimum integration time is 10 seconds (100 shots).

The GLOW molecular receiver is designed to operate in the clear air regions of the free troposphere and lower stratosphere. This provided some challenges for the IHOP experiment which was focused on convective activity in the boundary layer and lower troposphere. The photon counting PMTs provide high detection sensitivity in the upper troposphere and stratosphere where the return signals are small. One side effect of this is that when the maximum laser pulse energy and the full telescope aperture are used the signals collected from ranges less that 5 km are too large and the response of the photon counting detectors is non-linear. To ensure coverage of the most important altitudes for observations of convective activity and boundary layer evolution, the signal levels were optimized by reducing the pulse energy to between 5 mJ and 40 mJ. In addition, the effective telescope aperture was reduced from 45 cm to 25 cm. The low laser average power (0.05 W to 0.4 W) and reduced collection area means that some averaging (spatial and/or temporal) is required in post processing to obtain good performance above the boundary layer.

Lidar Observations

During the IHOP experiment GLOW was operated in several modes. The most common mode was a step stare scanning mode, in which the lidar 'stares' for 30 seconds at a fixed elevation angle along each of the four cardinal directions. A final 30 sec zenith pointing measurement is made before repeating the cycle. The typical azimuth angle sequence is 270°, 0°, 90°,180° as shown in Figure 2. Elevation angles of 15°,30° and 45° were used depending on conditions. The radial wind profiles along each of the azimuth directions can be derived and the horizontal wind speed

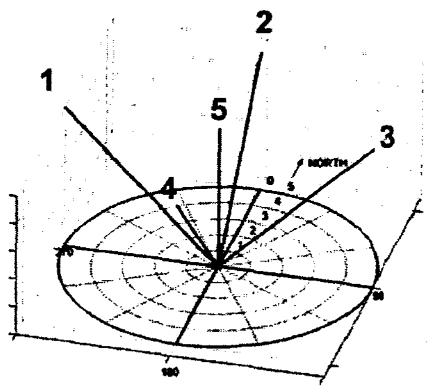

Figure 2 – Five direction scan pattern used for most of the IHOP observations. North is into the page.

and direction can be determined from the four line-of-sight profiles. An example series of wind profiles obtained with GLOW operating in this step stare scanning mode is shown in Figure 3. This time series of wind profiles was obtained during a low level jet experiment on the morning of June 20, 2002. The elevation angle was 45° and the four radial wind profiles have been combined to derive the wind speed and direction. The lidar signals have been averaged to a vertical resolution of 100 meters and the temporal resolution is 3 minutes per profile. The maximum errors are around 3 m/s, generally observed at the highest altitudes where the signal levels are decreasing. Of particular interest is the notable drop in wind speed observed in the lowest kilometer beginning at 0600 UTC. This drop in wind speed is coincident with the arrival of a bore wave at the Homestead site. The bore is observed as an apparent drop in wind speed from a maximum of 24 m/s to a minimum of around 3 m/s. Three oscillations of the bore wave with a period of about 1 hour are observed in the lowest kilometer.

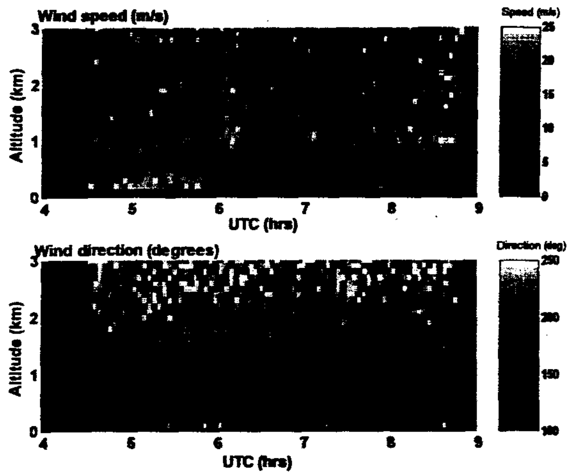

Figure 3 – Time series of GLOW wind speed (top) and direction (bottom) profiles from June 20, 2002. The drop in speed observed first at 0600 UTC coincides with the arrival of a bore wave.

In addition to the five direction step-stare scanning mode described above, a number of other step-stare scan patterns were used for special cases. A total of 244 hours of lidar wind profiles were obtained in the IHOP experiment. Of this total, 211 hours are from the five direction scans and the remaining 33 hours from operation in other modes.

3. Summary

The GLOW Doppler lidar completed an intensive field campaign in the spring of 2002 as one of many instruments operated in the IHOP_2002 field experiment. Validation of the GLOW wind profile data set from IHOP is ongoing.. The initial data release has been archived and made available to the scientific community. A number of case studies of events (drylines, bores, low-level jets) have been identified as candidates for further study with members of the IHOP scientific community.

Acknowledgements

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